

under tension, even if T_2 is artificially created, the rope will wrap back on itself because of spiraling of the wraps. Due to the uneven tension and uneven placement of that tension along the drum, an axial restoring force appears which pulls the taut first wrap (T_1) toward the loose wrap at tensioner 10. When the rope wraps back on itself, it binds, preventing any further pulling.

[0054] In the illustrated device, the rollers 9 positioned along the capstan provide a restoring force in the axial direction to keep the wraps from backing up and binding. The rotating guide 15 applies back-force to the first (and tightest) wrap where tension is T_1 , (and therefore the most force is necessary to move that wrap down the drum). The splines 12 facilitate the use of the rollers 9 and rotational guide 15 by allowing circumferential gripping and torque application in the correct rotational direction, while allowing the tensioned wraps to be moved axially along the drum as they enter and exit the device. While this particular embodiment works well as illustrated, any sort of material or feature (such as other edge profiles, re-cycling sliders, pivots, and rollers) providing similar anisotropic friction conditions could be used as effectively.

[0055] An additional embodiment of the splined drum is one that changes diameter along its longitudinal axis in order to aid axial movement of wraps along its body. This could aid in the movement of the high-tension wraps as pushed by the rollers 9.

[0056] This illustrated embodiment of the rope pulling device enables new capabilities in pulling ropes and cables at high forces and speeds. The embodiment described utilizes a high-power DC electric motor 4, as built by Magmotor Corporation of Worcester, MA (part number S28-BP400X) which possesses an extremely high power-to-weight ratio (over 8.6 HP developed in a motor weighing 7 lbs). The batteries 3 utilized are 24 V, 3AH Panasonic EY9210 B Ni-MH rechargeable batteries. The device incorporates a pulse-width modulating speed control, adjusted by squeezing the trigger 16, that proportionally changes the speed of the motor. This embodiment is designed to lift loads up to 250 lbs up a rope at a rate of 7 ft/sec. Simple reconfigurations of the applied voltage and gear ratio can customize the performance to lift at either higher rates and lower loads, or vice-versa.

[0057] Any embodiment of the design as described above can be used to apply continuous pulling force to flexible tensioning members (strings, ropes, cables, threads, fibers, filaments, etc.) of unlimited length. Also since the design allows for attachment to such a flexible tensioning member without the need of a free end, significant versatility is added. The design allows for a full range of flexible tensioning members to be utilized for a given rotating drum 8 diameter, further enhancing the usability of such a pulling device.

[0058] A further embodiment of the invention is illustrated in FIGS. 6, 7 and 8. This embodiment operates on a number of the same simple principles as the embodiment of FIGS. 2 through 4, but relies on slightly different implementations of those principles. Rope enters the device by wrapping around the safety cam 2. This cam is a modified version of a Petzl Grigri rope belayer/descender, and uses a self-help pinching mechanism to prevent unwanted backward motion of a rope or cable. The handle allows the user to manually

override that safety clamp in order to control a descent or back-driving of the rope through the device.

[0059] After the safety cam 2, the rope is wrapped around the pulleys 7 to be guided tangentially onto the rotating drum 8 within the spiral of the helix guide 19. The rope is wrapped through the turns of the helix guide 19, and the tensioning roller housing 20 is opened away from drum 8 to accept the rope as it goes through. Then the tensioning roller housing 20 is closed and clamped tight to the base of the helix guide S, which applies pressure from the tensioning roller 10 to the rope, clamping the rope against the tensioning drum 22.

[0060] Operation of this embodiment by a user is identical to that of the embodiment described above; the trigger 16 is squeezed, controlling the speed of the motor 4, which applies torque to the rotating drum 8 through the gearbox 6. The rope is gripped around the rotating drum 8 by the tension T_1 on the rope entering the device, as guided by the safety cam 2 and pulleys 7, and according to equation [1]. The tension T_2 which is necessary to make the device work is applied via the tensioning roller 10, as it is clamped by the tensioning roller housing 20. However, unlike the previous embodiments, instead of creating a no-slip condition to achieve T_2 , a dynamic friction is utilized to tug on the rope, creating the needed tension in the free end.

[0061] This is accomplished by the tensioning drum 22 having a larger diameter than the rotating drum 8. Since both are attached to the same drive shaft out of the gearbox 6, they have the same rotational velocity. But because of the bigger diameter on the tensioning part of the drum 22, the surface velocity is greater. Because more turns (and the higher tension turns) in the rope are along the original diameter on the drum 8, rope is fed at the rotational velocity times the diameter of drum 8. Since the tensioning drum 22 has a greater diameter, it constantly slips against the surface of the rope. The normal force of the rope against drum 22 is increased by the tensioning roller, allowing for a greater pulling force to be created by drum 22. Thus, the dynamic friction against the last turn of the rope creates a constant T_2 which is the basis for the operation of the device, as per equation [1].

[0062] The problem of the rope wrapping back on itself is solved with the helix guide 19, which guides the rope onto and off of the rotating drum 8. Splines may not be used in this version, since it is more useful for smaller loads and the anisotropic friction is not a required feature. The helix guide 19 continually pushes the wraps axially down the drum 8, since the helix 19 is stationary and the rope must move. It provides the same function as the rollers 9 in the preferred embodiment, however with more friction. The helix 19 also still accommodates utilization of the rope or cable at any point, and the design for this embodiment does not require a free end of the rope to be strung through.

[0063] A user attaches to the device (or attaches an object to the device, or the device to ground) via the attachment point 11 as in the previous embodiment. The ergonomic handle 5 with speed-controlling trigger 16 provide easy use similar to that of a cordless drill. The batteries and motor can be the same as in the previous embodiment. This embodiment of the design, however, may be less expensive to manufacture and more useful in applications where continuous pulling of a flexible tensioning member is necessary under lower loads (e.g., less than 250 lbs).